POWER COMPENSATION BY DISTRIBUTED GENERATION

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“References of information from other sources are quoted accordingly; otherwise the information presented in this report is solely work of the author.”

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ABSTRACT

In order to reduce electricity cost, together with improving the performance of distribution systems, it has to deal with the problem of power losses minimisation. Although losses in the system can never be entirely eliminated, they can be controlled and minimised in several ways for example by installing Distributed Generation (DG) and shunt capacitor. DG can reduce line losses, increase system voltage profile, and improve power quality of the system. The shunt capacitor can be improving the power factor if the installation DG affects the power factor of network system. In this thesis, the proposed method is tested on standard IEEE 14 bus system and the results of the simulation carried out using MATLAB. While, DIgSILENT software was used to simulate the 26-bus test system by. By adding the DG, the losses of the system will be reducing while it can stabilize the network system. Therefore, distributed generation has improved the overall system performance.

ABSTRAK

Untuk mengurangkan kos elektrik, bersama-sama dengan meningkatkan prestasi sistem pengedaran, ia hendaklah berdepan dengan masalah meminimumkan kehilangan kuasa. Walaupun kehilangan (kuasa) dalam sistem tidak pernah dilhilangkan sepenuhnya, ia dapat dikawal dan diminimumkan dalam beberapa cara misalnya dengan memasang Penjana Agihan (DG) dan selari kapasitor. Penjana Agihan (DG) dapat mengurangkan kehilangan pada litar, meningkatkan profil sistem voltan, dan meningkatkan kuasa kualiti pada sistem. Selari kapasitor dapat memperbaiki faktor kuasa jika pemasangan penjana agihan (DG) mempengaruhi faktor kuasa dalam sistem rangkaian.Dalam kajian ini, kaedah yang dicadangkan ini diuji pada standard 14 sistem bas IEEE dan hasil simulasi dilakukan dengan menggunakan perisian MATLAB. Sementara itu, DIgSILENT perisian digunakan untuk mensimulasikan sistem uji 26-bas. Dengan menambah Penjana Agihan DG, kehilangan kuasa pada sistem ini akan dikurangkan sementara itu ia boleh menstabilkan sistem rangkaian sesuai dengan permintaan pelanggan. Oleh kerana itu, Penjana Agihan (DG) telah meningkatkan prestasi sistem secara keseluruhan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE NO	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Background

The electric utility industry can trace its beginnings to the early 1880s. The earliest distribution system surrounded Thomas Edison's 1882 Pearl Street Station in lower Manhattan, using direct current (DC) placing small generators right next to the load. The fast growth of electricity demand and the development of high-voltage power transmission lines using alternating current (AC) encouraged electric utilities to build larger generators near the primary energy source (example: coal mines, water dams, etc.) and use transmission lines to deliver electricity to load centers, sometimes over spans of hundreds of miles. As a result of this production scheme electric utilities made technological advances by constructing larger generating plants to capture economies of scale [7].

A general definition was then suggested in which are now widely accepted as follows: "Distributed Generation is an electric power source connected directly to the distribution network or on the customer site of the meter" [1]. The definitions of DG do not define the technologies, as the technologies that can be used vary widely. However, a categorization of different technology groups of DG seems possible, such as, non-renewable DG and renewable DG. From distribution system planning point of view, DG is a feasible alternative for new capacity especially in the competitive electricity market environment and has immense benefit such as: Short lead time and low investment risk since it is built in modules, Small-capacity modules that can track load variation more closely, Small physical size that can be installed at load centers and does not need government approval or search for utility territory and land availability, Existence of a vast range of DG technologies. For these reasons, the first signs of a possible technological change are beginning to arise on the international scene, which could involve in the future the presence of a consistently generation produced with small and medium size plants directly connected to the distribution network (LV and MV) and characterized by good efficiencies and low emissions. DG provides electric power thereby eliminating the need to upgrade transmission lines and increase the capacity of remote power plants [13]. This will create new problems and probably the need of new tools and managing these systems.

Shunt capacitor banks (SCB) are installed at primary feeders in electric power distribution systems to improve voltage profiles and the power factor as well as to reduce power losses generated by the flow of reactive power in the system [8]. The use of SCBs has increased because they are relatively inexpensive, easy and quick to install and can be deployed virtually anywhere in the network. Its installation has other beneficial effects on the system such as: improvement of the voltage at the load, better voltage regulation (if they were adequately designed), reduction of losses and reduction or postponement of investments in transmission. The main disadvantage of SCB is that its reactive power output is proportional to the square of the voltage and consequently when the voltage is low and the system needs them most, they are the least efficient [11].

1.2 Project Objectives

1) To analyse the impact of Distributed Generation (DG) interconnection to the existing distribution network in term of voltage control and system losses

2) To compare the effect of Distributed Generation with Shunt Capacitor Bank in network system in term of power factor improvement and system losses.

1.3 Problems statement

Distributed generators are small, decentralized power plants situated closed to end user. The generators can supply electricity to a single location, or pump power directly into national electricity grids. Distributed Generation is the best answer to energy supply shortfalls because the traditional electricity grid will never be able to satisfy today’s needs for quantity or quality of power. Therefore, DG was installed in the network power system to fulfill the demand of the power from the consumer.

Distributed generation will change the power flows in the network and so will change network losses. If a small DG is located close to large loads then the network losses will be reduce as both real and reactive power and power can be supply to the load from the adjacent generator. But, if the large DG is located far away from network loads then it’s likely to increase losses on the distribution system. Hence, the DG will bother the stability of the power flow and the network system in term of voltage level and system efficiency.

By adding the DG in the distribution network, the power flow of the network will change and it also will change the network losses. But after adding the DG, the power factor of the system will change either improved or not. And the DG must be maintenance for four or five year after do the installation of it. If the system DG was shut down for maintenance, the network system will be change automatically and it will cause the increasing of losses. Hence, injecting the reactive power (shunt capacitor) is the best option to solve this power factor problem while it also can reduce the losses of the network system.

1.4 Project Scopes

This analysis study will focus on the effect of the impact of the performance on existing distribution network by adding the DG only in term of network losses of the system by using the MATLAB and DIgSILENT software. The limitation of getting the real data from utilities for the base case systems have decide to utilise the IEEE Reliability Test System of 14 bus as the test systems will use by MATLAB software and 26-bus test system will be simulate by using DIgSILENT software. The network system will be analysing for improvement the power factor and to stabilize the network system by adding the capacitor bank. DigSILENT software was use to simulate the network system by continuing the network system using the same 26-bus test system. The limitation of this simulation will only use the network that was improvement by the DG in the system.

1.5 Thesis outline

This thesis contain of 5 chapters they include Chapter 1: Introduction, Chapter 2: Literature reviews, Chapter 3: Methodology, Chapter 4: Result and discussion and Chapter 5: Conclusion and Recommendations. Each chapter will contribute to explain different focus and discussion relating with the corresponding chapters heading.

Chapter 1 contain introduction which present about the overviews of the project that is constructed. It consists of project background, objective, problem statement and project scope.

Chapter 2 contain literature review which discussed about the reference that is taken for this project completion.

Chapter 3 will discuss about the methodology in this project which consist of characteristic study of Distributed Generation and Capacitor Bank in power the network system. This chapter also discuss the software that was used to simulated and analysed the system

Chapter 4 contain result and discussion focused on the analysis of the result from the simulating the network systems and discussed the outcome that is obtained. The results was getting by analysis from both of software and was discuss with the results.

Chapter 5 contain conclusion and recommendations for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Distributed Generation

2.1.1 Introduction

Electrical power systems are complex networks and devices interacting to reliably generate transmit and distribute electrical energy to its customers. Centralized generation (CG) supplies large amounts of electrical energy from generators through transmission lines and distribution lines to the consumption area. The electrical demand around the world is growing continuously and presents some limitations to the CG model. Each mile of transmission line costs about one (1) million dollars to construct and approximately seven (7) percent of electricity is lost during the transmission as heat [9]. To provide reliable and less expensive electrical energy to customers, new emphasis is being placed on DG. Figure 2.1 shows differences between centralized generation and distributed generation.

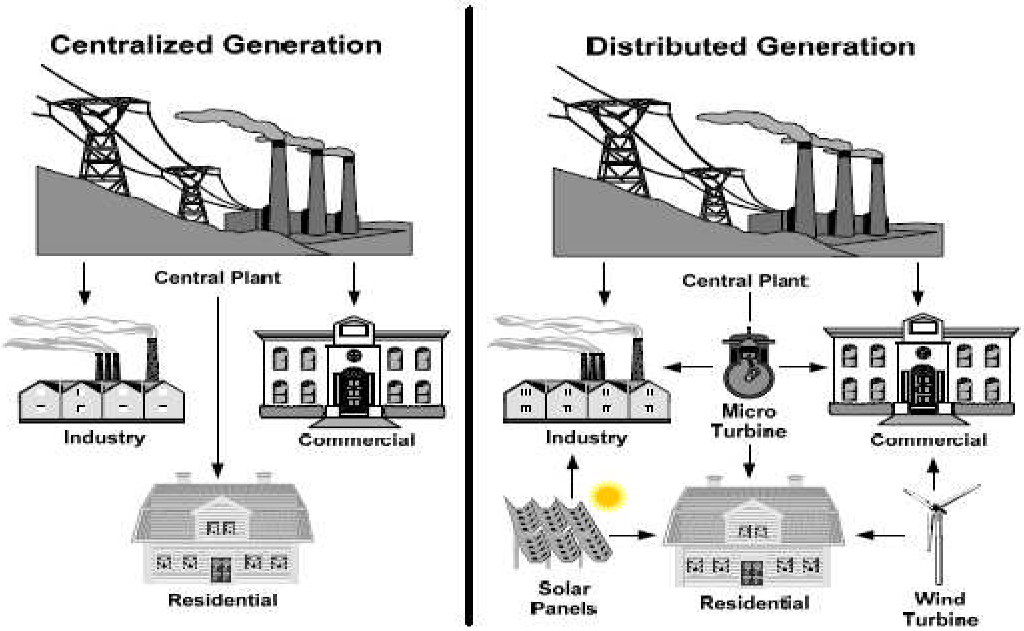

Figure 2.1: Centralized Generation vs. Distributed Generation [9]

Different technologies are being developed to generate electrical energy close to the consumption areas (load centers). Distributed generators are small, decentralized power plants situated closed to end user. The generators can supply electricity to a single location, or pump power directly into national electricity grids. Distributed Generation (DG) is the best answer to energy supply shortfalls because the traditional electricity grid will never be able to satisfy today's needs for quantity or quality of power. Generally, the capacity range of distributed generation is between 100 kW and 10 MW. Therefore, DG was installed in the network power system to fulfill the demand of the power from the consumer. Before installing distributed generation, its effects on voltage profile, line losses, short circuit current, amounts of injected harmonic and reliability must be evaluated separately. The planning of the electric system with the presence of DG requires the definition of several factors, such as: the best technology to be used, the number and the capacity of the units, the best location, the type of network connection, etc. The impact of DG in system operating characteristics, such as electric losses, voltage profile, stability and reliability needs to be appropriately evaluated.

Reduction of power losses by Distributed Generation (DG) is becoming a popular technique worldwide. Since an integration of DG into distribution systems will alter the power flows, it is obvious that the power losses in the system are affected. DG is utilized for improving the system voltage profile, power quality, system reliability and security.

2.1.2 Technology of DG

A key factor when implementing DG is the underlining technology. Technologies can be separated in generation and storage. Generation is further divided into conventional and nonconventional. Conventional includes combustion turbines, diesel engines, micro-turbines and natural gas engines. Non-conventional are mostly renewable energy technologies. Table 2.1 summarizes preliminary cost, size and efficiency estimates for DG technologies [9]. An important factor to consider is the relation between fixed and variable costs. Depending on the technology, DG could have high installation costs, but low operation and maintenance (O&M) costs. Thus, depending on the application, investing in DG technologies could be a feasible long term alternative.

Table 2.1: Distributed Generation Technologies [9]

Technology	Size Range (kW)	Installed Cost ($/kW)	Variable O&M ($/kWh)	Heat Rate (BTU/kWh)	Approx. Efficiency (%)
Diesel Engine	1-10,000	350-800	0.025	7,800	45
Natural Gas Engine	1-5,000	450-1,100	0.025	9,700	35
Dual Fuel Engine	1-10,000	625-1,000	0.023	9,200	37
Micro-turbine	15-60	950-1,700	0.014	12,200	28
Combustion Turbine	300-10,000	550-1,700	0.024	11,000	31
Fuel Cell	100-250	5,500+	0.01-0.05	6,850	50
Photovoltaic	Limited by Available Space	7,000-10,000	0.002	--	N/A
Wind Turbine	0.2-5,000	1,000-3,000	0.010	--	N/A

2.1.3 DG application in network system

Many researchers have been working in the DG field to minimize power losses and also include the effect of voltage profile and also will effect of the efficiency of the overall system. Authors in [1] have presented an Evolutionary Algorithms to determine a near optimal location of the DG with respect to system losses. Genetic Algorithm (GA) was apply to present the result of optimize the location of DG in this paper. Genetic Algorithm is a general- purpose search techniques based on principles inspired from the genetic and evolution mechanisms observed in natural systems and populations of living beings. Their basic principle is the maintenance of a population of solutions to a problem (genotypes) as encoded information individuals that evolve in time. Generally, GA comprises three different phases of search:

Phase 1: creating an initial population;
Phase 2: evaluating a fitness function;
Phase 3: producing a new population.

A genetic search starts with a randomly generated initial population within which each individual is evaluated by means of a fitness function. Individual in this and subsequent generations are duplicated or eliminated according to their fitness values. Further generations are created by applying GA operators. This eventually leads to a generation of high performing individuals. The main goal of the proposed algorithm is to determine the best locations for new distributed generation resources by minimizing loss reduction and voltage profile Improvement.

In [3], an optimization method was used to analyze the Sizing and Placement. The unique radial distribution structure is exploited in developing a Fast and Flexible Radial Power Flow (FFRPF) method to deal with a wide class of distribution systems. The FFRPF technique is incorporated in both utilized deterministic and metaheuristic optimization methods to satisfy the power flow equality constraints requirements. In the deterministic solution method, the DG sizing problem is formulated as a nonlinear optimization problem with the distribution active power losses as the objective function to be minimized, subject to nonlinear equality and inequality constraints. Endeavouring to obtain the optimal DG size, an improved version of the Sequential Quadratic Programming (SQP) methodology is used to solve for the DG size problem. The conventional SQP uses a Newton-like method, which consequently utilizes the Jacobean, in handling the nonlinear equality constraints. The radial low X/R ratio and the tree-like topology of distribution systems make the system ill-conditioned. A Fast Sequential Quadratic Programming (FSQP) methodology is developed in order to handle the DG sizing nonlinear optimization problem. The FSQP hybrid approach integrates the FFRPF within the conventional SQP in solving the highly nonlinear equality constraints. By utilizing the FFRPF in dealing with equality constraints instead of the Newton method, the burden of calculating the Jacobean and consequently its inverse, as well as the complications of the ill-conditioned Y-matrix of the RDS, is eliminated. Another advantage of this hybridization is the drastic reduction of computational time compared to that consumed by the conventional SQP method. In this thesis, a new application of the Particle Swarm Optimization (PSO) method in the optimal planning of single and multiple DGs in distribution networks is also presented. The algorithm is utilized to simultaneously search for both the optimal DG size and its corresponding bus location in order to minimize the total network power losses while satisfying the constraints imposed on the system. The proposed approach hybridizes PSO with the developed distribution radial power flow, i.e. FFRPF, to simultaneously solve the optimal DG placement and sizing problem. The difficult nature of the overall problem poses a serious challenge to most derivative based optimization methods due to the discrete flavour associated with the bus location, in addition to the sub problem of determining the most suitable DG size. Moreover, a major drawback of the deterministic methods is that they are highly-dependent on the initial solution point. The developed PSO is improved in order to handle both real and integer variables of the DG mixed-integer nonlinear constrained optimization problem. Problem constraints are handled within the proposed approach based on their category. The equality constraints, i.e. power flows, are satisfied through the FFRPF subroutine while the inequality bounds and constraints are treated by exploiting the intrinsic and unique features associated with each particle. The proposed inequality constraint handling technique hybridizes the rejection of infeasible solutions method in conjunction with the preservation of feasible solutions method. One advantage of this constraint handling mechanism is that it expedites the solution method converging time of the Hybrid PSO (HPSO).

In [4], a methodology for evaluating the effects of DG sizing and sitting in terms of reliability, losses and voltage profile has been introduced. Conceptually, the methodology is based on the following methods:

1) The electric losses and voltage profile evaluation is based on a power flow method with the representation of generators (PV buses).
2) The reliability indices evaluation is based on analytic methods modified to handle multiple generations.

The proposed methodology can be used as standalone by a specialist to evaluate different DG installation alternatives or it can be used as integral part of an automatic optimization method. The methodology adopted in this work is based on the power summation method with each DG unit represented by a PV bus with specified voltage magnitude. The PV bus is modelled as a network breakpoint. At every each iteration, the voltage mismatch between the two sides of the breakpoint is calculated and reactive power injections are calculated in order to correct the voltage mismatch. This process continues until the voltage mismatch is less than an acceptable tolerance. In the developed methodology on distribution reliability evaluation, it is considered that the DG can supply all or part of the load in the case of main source unavailability. It is also considered that the occurrence of a failure causes the disconnection of both the main supply and the DG from the system. After the isolation of the fault via proper switches operation, the DG is re-connected to the system. In this way, the frequency related indices are not modified in the presence of DG. On the other hand, there will be a reduction on duration related indices since part of the load can be attended by DG while the main supply interruption cause is being repaired. This benefit is greater is the DG energy source is considered always available and the units can be prescheduled.

In [5], line losses reduction of the network system was analyze of Distributed Generation in Electrical Distribution Systems. This paper focuses on line loss reduction analysis. In this study, one-concentrated load is assumed at the end of the line. With the introduction of DG, line loss reduction can be expected. This factor is analyzed, quantified and presented in this paper for different locations of the DG along the feeder and for different DG power outputs. Two simple radial systems are considered:

(I) System without DG

(II) System with the inclusion of DG.

Electrical line loss occurs when current flows through transmission and distribution systems. The magnitude of the loss depends on amount current flow and the line resistance. Therefore, line loss can be decreased by reducing either line current or resistance or both. If DG is used to provide energy locally to the load, line loss can be reduced because of the decrease in current flow in some part of the network. DG can be operated in three modes: lagging or leading or unity power factor. Under lagging power factor operation, DG produces reactive power for the system. Thus, Q is positive. Also Q is negative for leading power factor operation because DG absorbs reactive power from network. There are four possible combinations of power factors of load and DG.

Case 1, DG operates at a lagging power factor while load has leading power factor.
Case 2, DG operates at a lagging power factor and load is also lagging.
Case 3, DG operates at a leading power factor and load is leading as well.
Case 4, DG operates at a leading power factor while load has lagging power factor.

In [6], the author was investigated the impact of utilizing selected DG units with different penetration levels on the various forms of power system stability. A hypothetical network with two conventional power plants and many DG units is simulated. The DG can improve the stability of power systems if suitable types and appropriate locations are selected. Regarding the oscillatory stability, the utilization of DG improves the damping of the electromechanical modes and slightly increases their frequency. This fact is confirmed through the time-domain simulation of some